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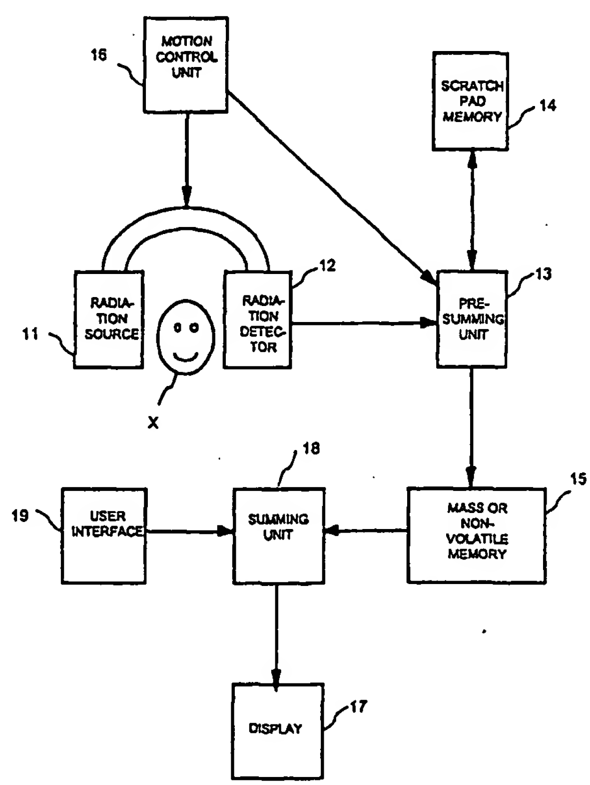
(57) Abstract

The present invention relates to a tomosynthetic imaging method and apparatus, in which invention the target to be imaged is transilluminated by means of the radiation obtained from a radiation source, the said radiation is detected using an electric radiation detector, and images are taken of the target from different directions. An essential feature of the said invention is that before the recording of the image data obtained in the imaging process, the amount of the said image data is reduced by pre-summing the primary image data so as to obtain a smaller number of pre-summed images the properties of which almost correspond to those of primary images, at which point the said pre-summed images are recorded. The said invention also allows for implementing the tomosynthesis by means of equipment other than that provided with a massive memory and information processing capacity.



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Method and apparatus for tomosynthetic imaging

The present invention relates to a tomosynthetic imaging method in which method the target to be imaged is transilluminated by means of the radiation obtained from a radiation source, the said radiation being detected by means of an electric radiation detector and images of the target being taken from different directions.

The said invention also relates to an apparatus in tomosynthetic imaging which apparatus encompasses a radiation source, an electric radiation detector, means for moving at least either of these with regard to the target to be imaged, a unit for controlling the motion of the radiation source and/or the detector, and means for processing the image information.

Tomosynthesis is an imaging method generally known in the field of magnetic and x-ray imaging. It involves taking images of the target at different angles and summing them in such a way that they overlap in the desired manner, so as to sum and overlap the points of interest in the target and to blur invisible the features that are outside of the layer concerned. When all the images are recorded, the image data can be manipulated in the desired manner later, the layer to be imaged can be selected arbitrarily, and the image of the desired layer improved, for example, by subtracting from it images of the other layers. This can be repeated iteratively.

The process of image manipulation in tomosynthesis is the slower the larger the byte mass processed. The recording of large quantities of information invariably also entails costs. In many cases some of the images could, in principal, be left unrecorded without this in any way impairing the quality of synthetised images. In the case of x-ray imaging, however, that regarding man in particular, this is not possi-

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ble. It is not recommended that the human body be subjected to radiation unnecessarily. In addition, all x-ray images taken of man must be recorded, at least on ethic grounds and often also as prescribed so by regulations issued by the authorities.

In tomosynthesis, the tomographic angle, that is, the angle of projection between primary images, affects the thickness of the layer which is imaged of the target at the image manipulation stage in that the greater the angle, the thinner the layer imaged. In addition, the angles between different images do not have to be identical, though they usually are. Furthermore, the angles need not be on the same plane either but the target can be imaged at different angles in 3D set of coordinates, which generally contributes to blurring of the undesired layers. The scope of blurring is inversely proportional to the number of transillumination images N in that the features of the unwanted layers dim away by a coefficient 1/N.

The imaging process involved in tomosynthesis can be examined by adopting the Nyquist criterion that can be expressed e.g. in the form sampling frequency = 2 x the highest frequency of interest. Thus, in electric imaging that utilises a scanning beam, for example, the distance travelled by the ray in the layer to be imaged = the pixel size of the sensor, including magnification. If one examines the panoramic imaging of the dental arch, for example, in which the beam typically travels approximately 300 mm, and if the resolution requirement is set at 3 lp/mm, the sensor pixel size in the horizontal direction will be approximately 160 μm and the number of samples approximately 1680 / sensor pixel / row. Correspondingly, if the sensor height is 120 mm, the vertical direction will give us 720 pixels, in which case the size of one transillumination image will be approximately 1,2 megapixels. Thus, the recording of the amount of information produced by a beam of width 30 mm in imaging that utilises the FT technology (Frame

Transfer) would require approximately 180 megabytes of memory. The implementation of tomosynthesis in such a way would require such a large number of images that it would be extremely difficult and time-consuming to record and process the resulting quantities of data using the information processing equipment available at present.

Measures have been taken in recent few years to also apply digital imaging to mammography, for example. The resulting enormous amount of image data constitutes a problem even in these applications, as transillumination alone produces dozens of megabytes. The capacity of the information processing equipment generally in use in the field would be completely inadequate if an attempt was made to construct tomosynthetic images on the basis of images of this kind.

The tomosynthesis method has been discussed e.g. in the article TOMOSYNTHESIS: A Three-Dimensional Radiographic Imaging Technique, David G. Grant, IEEE Transactions on Biomedical Engineering, Vol. BME-19, No. 1, January 1972. According to the article, in practise approximately 20 images already produce a tomosynthetic effect equivalent to a normal tomosynthetic image. Although increasing the number of images basically improves the tomosynthetic effect, the effect that would be reachable is seldom significant enough for justifying the use of a much greater number of images, at least a number of a higher order of magnitude.

The US patent publication 5,195,114, representing prior art in the field, describes a type of equipment applicable to digital imaging. The said equipment encompasses a x-ray source that rotates around the target to be imaged, a x-ray detector, and means for recording and processing the image data. According to the publication, the panoramic imaging of the human dental arch produces 900 images the recording of which requires an enormous memory capacity. In addition, when

acting in the manner described in the said publication, the distance between the individual images would be approximately 0.3 mm, which in the beam widths typically employed in the aforementioned context would mean that the target would only be presented in approximately 13 images. The maximum blurring ratio would thus be 1/13. As blurring tends to increase with the angle between the individual images, the obtaining of satisfactory images would in practise require the use of a wider beam or the taking of images at shorter intervals, that is, the recording of an even larger number of images.

Another type of equipment applicable to digital tomographic imaging is presented in the US patent publication 5,677,940, which equipment encompasses a x-ray source that rotates around the target to be imaged, a x-ray detector, and means required for information processing and for other control of the apparatus. According to the publication, x-ray radiation is converted to light and the signal converted to electric form by using a MOS sensor (Metal Oxide Semiconductor) before the image data are recorded in the memory.

A semiconductor sensor has been presented in the international patent publication WO 95/33332 in which sensor x-ray radiation is converted directly to electric form. The losses resulting from collecting the image data by means of this type of sensor are much smaller than those produced by the sensor employed in the solution that is presented in the US patent publication 5,677,940, and the tomosynthetic images that can be achieved by the said type of sensors are of a better resolution.

A prior art technique in medical imaging is the use of actual computer tomography in which the target is generally imaged in slices from all directions and the resulting image data are recorded, after which an image can be formed of any part of the target by calculatory means using methods based on the

so-called Radon transformation, or other calculation methods. The equipment used in computer tomography are extremely expensive, however, the images obtained are typically quite granular, and large doses of radiation have to be employed in order to obtain noise-free images. As a rule, the use of equipment of this kind is not possible nor justified in particular in dental x-ray imaging.

Traditionally, the equipment used in different tomographic methods is manufactured for use with just that particular method. However, the present trend favours the development of solutions by means of which a certain apparatus could be used for a variety of purposes, i.e. the aim is that the said equipment would allow for utilising different tomographic methods and for imaging varying types of projections. It would be desirable that solutions could be found, of a kind that would allow for low-cost imaging, even three-dimensional imaging, where necessary, by means of digital x-ray equipment as such already generally known in dentistry. This would diversify the use of such equipment and facilitate the purchase of equipment that utilise digital technology. Digital technology aids the work of doctors, among other things, in that it allows not only for the taking of more high-quality images and thus the making of more accurate diagnoses, but also allows for recording and administering the images in electric form together with all other documentation relating to the patients.

Thus, the objective of the present invention is to create a method for tomosynthetic imaging, in which method the aforementioned objectives have been approached and problems solved. Another objective is to create an apparatus which allows for implementing the method according to the invention.

The primary objective of the said invention is to create a tomosynthetic method in which at least the number of images to

be recorded permanently can be reduced, thereby also cutting down equipment costs and speeding up image processing in the forming of cross-sectional images. The methodological and equipment solutions, according to the invention, allow for tomosynthetic imaging that can be implemented using a known information processing technology and the existing equipment, without the need for a large memory capacity.

The most relevant features of the invention are presented in the characterising parts of the independent claims herewith enclosed. An essential feature of the invention is that the data obtained from imaging are not actually, that is, as such and/or permanently, recorded, but the primary image data are first pre-summed and it is the resulting pre-summed image data which are then recorded.

According to one preferable embodiment of the invention, the number of images used for forming tomosynthetic images is reduced by pre-summing adjacent images, that is, images taken at almost parallel angles, either upon reading the image data and/or after that. It is only then that the pre-summed images are recorded in the non-volatile memory, and the actual tomosynthetic image is formed on the basis of the said pre-summed images.

Reducing the amount of data to be recorded cuts down costs and speeds up the actual tomosynthesis. According to the present invention, the amount of information to be recorded can be reduced substantially in all types of tomosynthetic imaging regardless of the application and implementation concerned, thus also in light-based transillumination, for example.

A preferable solution, according to the invention, is to divide primary images into groups that are composed of more or less the same number of images, and even in such a way that the angle between the images that form a given group is small.

When all the images in these groups are pre-summed, by means of known tomosynthesis methods, and by using the assumed centre of the target to be imaged, for example, as the default layer, blurring is quite small within a relatively large distance on both sides of the default layer. The angle between the groups can also be arranged to be of desired magnitude. All the desired layers within a relatively large distance on both sides of the default layer can be formed on the basis of the pre-summed images.

If the pre-summing is performed after the imaging stage on the basis of the image data recorded in the scratch pad memory, the processing time required by the actual tomosynthesis stage can be reduced. On the other hand, not all primary images have to be recorded, not even in the scratch pad memory, if at least some of the pre-summing is performed at the imaging stage. This will reduce the required storage capacity even further.

According to one preferred embodiment of the invention, in x-ray imaging the radiation is detected by means of a sensor that converts x-ray radiation directly to an electric signal. According to yet another preferred embodiment of the invention, the said sensor is a TDI sensor (Time Delay Integration) which utilises CCD technology (Charge Coupled Device), in which case pre-summing can be conducted directly in the sensor at the image data reading stage.

In the following, some embodiments of the invention will be described in detail by way of examples by referring to the enclosed drawings, without restricting the present invention to the details of the said embodiments, however.

Figure 1 shows the imaging stage in tomosynthetic imaging.

Figures 2a and 2b show the principle employed in forming cross-sectional images in tomosynthesis.

Figures 3a, 3b, 3c and 3d show the principle, according to the invention, for pre-summing primary images and forming the cross-sectional images on the basis of the pre-summed images.

Figure 4 shows a piece of tomosynthetic imaging equipment, according to the invention, in the form of a block diagram.

Figure 5 shows one preferred embodiment of the invention in the panoramic imaging of the human dental arch.

Figures 6a and 6b show one radiation detector arrangement applicable to be used in the invention.

Figure 1 shows the principle employed at the imaging stage in tomosynthetic imaging. The target to be imaged is indicated in the figure by X and the cross-sectional layers of the target X by L1, L2, L3 and Lx. In the present example, three images S1, S2 and S3 are taken of the target X by placing the radiation source 11 in the places R', R'' and R''' and moving the radiation detector 12 correspondingly. The angle a1, a2 between the images determines the tomographic angle T of the synthesised image. If all the images S1, S2 and S3 are summed to form a tomosynthetic image, the tomographic angle T of the resulting cross-sectional image will be a1 + a2.

The imaging stage can also be implemented by keeping the radiation source 11, for example, stationary and moving the target to be imaged X and the radiation detector 12, or by keeping the radiation detector 12 stationary and moving the radiation source 11 and the target to be imaged X.

Figures 2a and 2b show the formation of the cross-sectional images P1 and P2 according to the prior art on the basis of

the images SN at the image manipulation stage. In Figures 2a and 2b, the images SN taken of the target X are summed in such a way that the features contained in a layer of the target X, which layer is assumed to be of interest, are imaged more accurately than the other layers. Assuming, for example, that the images S1, S3 and S5 in Figure 2a correspond to the images S1, S2 and S3 in Figure 1 and the images S2 and S4 to the projections imaged between these, the resulting tomosynthetic image P1 in Figure 2a would roughly represent the cross-sectional layer L1 shown in Figure 1.

Figures 3a, 3b, 3c and 3d show the principle of the pre-summing method, according to the invention. In Figures 3a and 3b, the pre-summed images Z1 and Z2 are formed on the basis of the images S1, S2 and S3 that have been taken over the area of one tomographic angle, and on the basis of the images S4, S5 and S6 that in turn have been taken over the area of another tomographic angle, respectively. The preferable embodiments of the present invention are based on the finding that if each pre-summing is performed over an area of a sufficiently small tomographic angle aN to form a suitable default layer Lx, which layer can be the assumed centre of the target to be imaged, for example, the number of images for use as the material for tomosynthetic image manipulation will be considerably smaller than the number required if no pre-summing was employed, and yet the pre-summed images will be almost equivalent to primary ones. According to the invention, the pre-summed images Z1 and Z2 can be recorded in the non-volatile memory in which case an unlimited number of the cross-sectional images PN, the layer thickness of which is determined by the tomographic angle T, can be formed later using known tomosynthesis methods. In Figures 3c and 3d, the images P1 and P2 were formed from the pre-summed images Z1 and Z2 on the basis of two cross-sectional layers by positioning the pre-summed images to overlap in different ways.

Thus, the best result, according to the invention, can be obtained by forming the pre-summed images ZN over the area of a small tomographic angle aN, which only causes minor blurring of the external features of the default layer. The angle of the pre-summed images ZN can be thought to represent the mean of the angles at which the images used in the pre-summing were taken. The minor blurring that occurs in pre-summing delimits the allowed distance between the default layer Lx and the cross-sectional layer of the image formed at the actual tomosynthesis stage.

The method, according to the invention, enables the pre-summed images ZN to be recorded in a space considerably smaller than that required by the recording of the primary images SN. The pre-summed images ZN can also be processed faster on account of their smaller number.

The pre-summing, according to the invention, can be performed at the imaging stage as new image information is created or once the imaging process has been completed. The actual cross-sectional image is formed only after the collection and pre-summing of the entire image data. In the panoramic imaging of the dental arch, for example, the pre-summed images can be formed on the basis of image data that e.g. correspond to 5-50 images which are purely composed of primary image information, preferably perhaps on the basis of information equivalent to 10-20 images, and the actual tomosynthetic image e.g. on the basis of 5-100 pre-summed images, possibly 10-50 images. The tomographic angle between the images to be pre-summed could be less than 5 degrees, for example, preferably not exceeding 1 degree, and the tomographic angle between the pre-summed images 1-45 degrees, for example, possibly 2-20 degrees.

The block diagram in Figure 4 shows a piece of equipment by means of which the tomosynthetic method, according to the invention, can be implemented. The said equipment encompasses

the radiation source 11, radiation detector 12, pre-summing unit 13, scratch pad memory 14, mass or non-volatile memory 15, a unit 16 for controlling the motion of the imaging equipment, the display 17, summing unit 18 and user interface 19. During the imaging process, the motion control unit 16 controls the reciprocal motion of the radiation source 11 and radiation detector 12 with regard to the target to be imaged X. The radiation detector 12 preferably converts the radiation, e.g. x-ray radiation, used for transillumination, directly to an electric signal. The signal is then converted to digital form and sent to the pre-summing unit 13 which is already capable of starting the process of pre-summing the primary images at the imaging stage with the help of the scratch pad memory 14 and the imaging equipment motion information 16. The scope of the pre-summing covers the desired number of images preferably taken over an area of a small tomographic angle and the resulting images are recorded in the mass storage 15. The desired cross-sectional layer can be selected later on an arbitrary basis via the user interface 19, keeping in mind the limiting conditions discussed above, which cross-sectional layer is calculated in the summing unit 18 and presented on the display 17. The cross-sectional layer can be selected in such a way that it passes through the target at any angle, or it can be a cylinder surface, for example.

Tomosynthetic images can be taken using a panoramic x-ray apparatus in which images of the target are taken by using a x-ray detector and a x-ray source capable of rotating around the target. In such a case, a very narrow x-ray beam e.g. of width 4-20 mm is employed, and as the x-ray detector a receiver is used by means of which the image information can be converted to electric form and from it to digital form. In Figure 5, for example, the radiation obtained from the radiation source 11 is directed through the target to be imaged X by means of the radiation detector 12, each of the vertical pixel rows of which can be considered to form a single-row sensor. As the

radiation source 11 and the detector 12 are moved in the known manner around the centre of revolution C and as the detector 12 thereby passes the target to be imaged, the apparatus produces, on the known slit imaging principle, the images SN that are essentially equivalent to transillumination images, that is, the first vertical row of the sensor produces the image SI, the second the image S2 etc. The resulting primary images SN can be recorded in the temporary memory as such. In one preferable embodiment of the invention, however, the image information which is created at the first point in time during the imaging process and which is to be summed to each of the be pre-summed images that will, is recorded, in which case the rest of the image data to be pre-summed to each image are summed directly to the image information recorded in the said scratch pad memory as they are generated during the imaging process.

The radiation detector 12 can also be provided to encompass sensor columns composed of several rows in which case the pre-summing can be performed by summing directly on the sensor the image information produced by the individual rows in each column, which summing already takes place upon the reading of the image data. Thus the image information read from the sensor does not correspond to the images SN shown in Figure 5, which images are purely composed of primary image data, but to the images ZN that have already been pre-summed and can be recorded directly.

The present invention can be implemented by using any sensor technology. According to one embodiment of the invention, a preferable solution in x-ray applications is to utilise a technology that enables x-ray radiation to be converted directly to electric form. This allows for reducing the loss encountered with more traditional sensor technologies in which the x-ray radiation first has to be converted to light, then to electric form, and finally to digital form.

A useful feature of the MOS technology, which is one of the more traditional sensor technologies, is that the image data collected on the sensor can be read directly from individual pixels. This eliminates the problem encountered in the CCD technology, in which the image data read also carry unwanted signal when the pixel charges are transferred from the image information reception area to the charges reading area via the neighbouring pixels. The problem can of course be minimised even with the CCD technology by utilising a sensor of the FT type in which case the pre-summing of the image data, according to the invention, is performed electronically or programmatically before the permanent recording of the information.

In spite of the certain problems mentioned above, one preferable way of pre-summing, according to the invention, is to use the CCD sensor as the radiation detector, which sensor is composed of several narrow, parallel TDI sensor columns and which sensor pre-sums the image data automatically at the image data reading stage. This solution allows for the avoiding of losses and interference at the pre-summing stage, and for reducing the speed required by AD conversion compared to that required by electronic or programmatic pre-summing. It is also preferable to place a recording/reading register beside each integration register so as to gain more time for the reading of data from the sensor. In addition, if a column clock is assigned to each narrow sensor of the above kind, the sensors can be read at their own specific speeds, where necessary, thus essentially reducing the so-called inherent unsharpness effect that denotes the unwanted blurring of the image due to the fact that it is possible to match the projection speed of only one point in the area of the beam exactly with the calculatory speed determined by the imaging provision. Thus, the greater the number of areas in the beam in which the projection speed can be adjusted to match the calculatory speed as accurately as possible, the smaller the unwanted blurring.

Pre-summing performed directly on the radiation detector can be illustrated with reference to one sensor structure shown in Figures 6a and 6b, which structure lends itself preferably to use in the present invention. Figure 6a shows the radiation detector 12' which has been divided into several columns, or in fact into narrow CCD sensor columns that operate on the TDI principle. Figure 6b shows one column or bar 12', according to Figure 6a, which column or bar encompasses an image information reception area 20, integration register 21 located beside the reception area 20, and preferably also a recording/reading register 22 provided beside the integration register 21. During the imaging process, the detector 12 is moved pass the target to be imaged during which movement the said detector 12 is constantly receiving radiation, e.g. x-ray radiation, that passes through the target. The means provided on the surface of the sensor, not shown in the said figure, thereby convert the radiation to light that contains image information. The pixels located in the reception area 20 convert the said light to an electric charge that corresponds to the intensity of light. The charges are transferred, one pixel at a time and controlled by the column clocks 25, towards the integration register 21 in which they are summed and the image data read 23 from the sensor via the recording/reading register 22 and controlled by the row clock 24. Thus, the image information read from each narrow sensor bar 12' is already in pre-summed form, according to the invention, the said pre-summing covering an area that comprises the width of the beam read by the sensor column and the tomographic angle that determines the rest of the imaging geometry.

In addition to the preferable embodiments presented above, the tomosynthetic method and apparatus, according to the invention, can be applied to the imaging of any target using x-ray radiation, or any other radiation that can be used for transillumination purposes. The present invention lends itself most particularly to use in the x-ray imaging of the human

skull, such as panoramic and other cross-sectional imaging of the dental arch, and in mammography. The implementation of the present invention is not restricted by the application of any particular sensor technology. The present invention preferably also allows for the use of sensors that are based on the direct detection of x-ray radiation. The following claims define the basic idea of the invention within which various details may vary and differ from the examples described above.

Claims

1. A tomosynthetic imaging method in which the target to be imaged is transilluminated using radiation, e.g. x-ray radiation, obtained from a radiation source, the said radiation being detected by means of an electric radiation detector, and images being taken of the target from different directions, characterised in that the resulting primary image information is at the first stage pre-summed and the actual tomosynthetic image is formed in a later stage of the said pre-summed images.

2. A method according to claim 1, characterised in that the image information is pre-summed over the area of such a small tomographic angle that the tomographic effect remains so small that the pre-summed images obtained are almost equivalent to transilluminated images.

3. A method according to claim 2, characterised in that the image information, of a kind in which the tomographic angle is less than 5 degrees, preferably less than 1 degree, is pre-summed.

4. A method according to any of the claims 1-3, characterised in that the pre-summing is performed in such a way that each pre-summed image is essentially composed of an equally large amount of primary image information, e.g. essentially of an equal number of primary images.

5. A method according to any of the claims 1-4, characterised in that in the panoramic imaging of the human dental arch in particular, pre-summed images are formed on the basis of image information that corresponds to 5-50 images purely composed of primary image information, preferably on the basis of information that corresponds to 10-20 images.

6. A method according to any of the claims 1-5, characterised in that in the panoramic imaging of the human dental arch in particular, the actual tomosynthetic image is formed of 5-100 pre-summed images, preferably of 10-50 images.

7. A method according to any of the claims 1-6, characterised in that in the panoramic imaging of the human dental arch in particular, the beam obtained from the radiation source is restricted to be extremely narrow in form, e.g. of width 4-20 mm.

8. A method according to any of the claims 1-7, characterised in that the pre-summing is at least partly performed during the reading of the image information.

9. A method according to any of the claims 1-8, characterised in that a sensor that converts x-ray radiation directly to electric form is used as the radiation detector.

10. A method according to any of the claims 1-9, characterised in that the pre-summing is performed electronically or programmatically.

11. A method according to claim 10, characterised in that before pre-summing, and possibly also during it, part of the image information, at preferably at least the part of it which is generated at the first point in time for each of the pre-summed images, is recorded in the temporary scratch pad memory.

12. A method according to any of the claims 1-8, characterised in that as the radiation detector a TDI sensor which utilises CCD technology is used, in which case the pre-summing is performed by summing the image information produced by two or more sensor pixel rows already on the sensor, before reading out the image data.

13. A method according to claim 12, characterised in that the said TDI sensor is arranged to encompass a number of narrow TDI sensors each of which constitutes a sensor column on the radiation detector, which column contains two or more sensor pixel rows.

14. A method according to claim 12 or 13, characterised in that each narrow sensor column is used via its own column clock.

15. A method according to claim 14, characterised in that the pre-summed images are read out from the radiation detector via the recording/reading registers positioned beside the integration registers of the narrow sensors.

16. A method according to any of the claims 1-15, characterised in that the pre-summed images are recorded in the mass storage, and the actual tomosynthetic image is formed on the basis of the said recorded, pre-summed images.

17. A method according to any of the claims 1-16, characterised in that the said method is used for imaging cross-sectional layers to obtain panoramic images of the human skull, in particular the dental arch, or of the soft tissue in the chest area.

18. An apparatus for tomosynthetic imaging, which apparatus encompasses a radiation source (11), e.g. an X-ray tube, a radiation detector (12), and means for moving at least either of these with regard to the target to be imaged (X), a unit (16) for controlling the motion of the radiation source (11) and the radiation detector (12), and means for processing the image information, characterised in that the means for processing the image information include means for pre-summing the said image information (12, 13, 14).

19. An apparatus according to claim 18, characterised in that the radiation detector (12) is a sensor that converts the radiation directly to electric form.

20. An apparatus according to claim 18 or 19, characterised in that the means for pre-summing the image information include a scratch pad memory (14) which is intended for the temporary recording, when required, of at least some of the image information.

21. An apparatus according to claim 18, characterised in that the radiation detector (12) is composed of narrow columns (12') that constitute a TDI sensor which utilises CCD technology.

22. An apparatus according to claim 21, characterised in that a column clock (25) is provided for each narrow sensor column (12').

23. An apparatus according to claim 21 or 22, characterised in that the narrow sensor columns (12') are composed of the image information reception areas (20), integration registers (21) located beside these, and possibly also of the recording/reading registers (22) located beside the said integration registers.

24. An apparatus according to any of the claims 18-23, characterised in that it encompasses means for recording the pre-summed images in a non-volatile memory (15) and means for forming the actual tomosynthetic images (18, 19) on the basis of the said pre-summed images recorded in the memory (15).

25. An apparatus according to any of the claims 17-24, characterised in that it is integrated into equipment, known per se, applicable to the cross-sectional imaging, e.g. pano-

ramic imaging, of the human skull, in particular of the dental arch.

26. An apparatus according to any of the claims 17-24, characterised in that it is integrated into mammography equipment known per se.

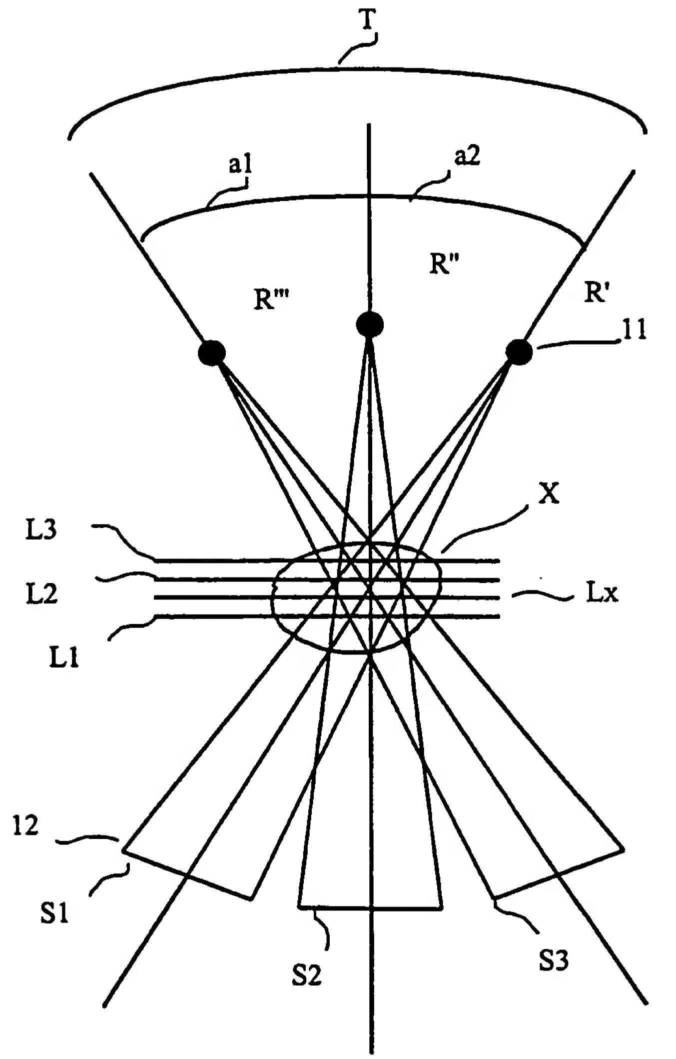

FIG 1

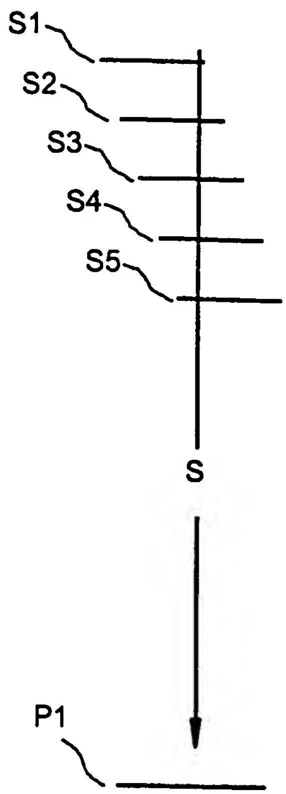

FIG 2a

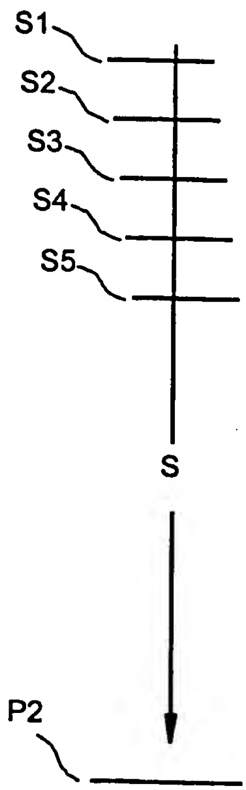

FIG 2b

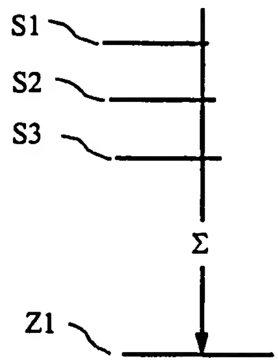

FIG 3a

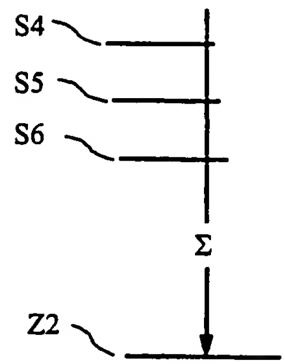

FIG 3b

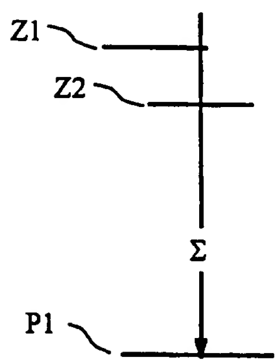

FIG 3c

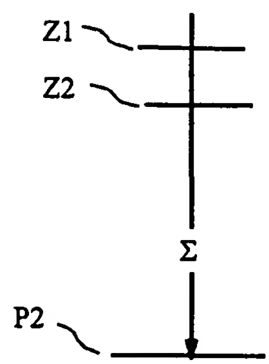

FIG 3d

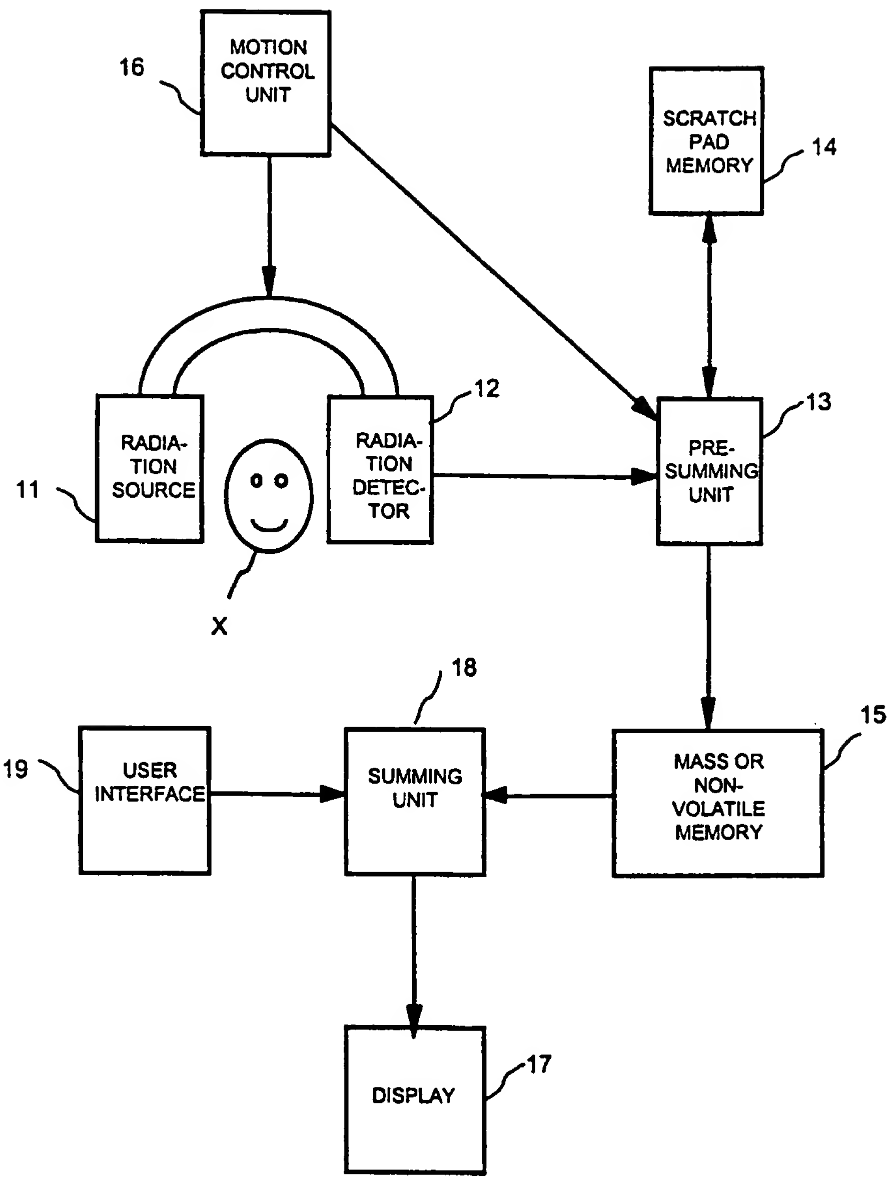
MOTION CONTROL UNIT
16
SCRATCH PAD MEMORY
14
RADIA-TION SOURCE
11
RADIA-TION DETEC-TOR
12
PRE-SUMMING UNIT
13
X
USER INTERFACE
19
SUMMING UNIT
18
MASS OR NON-VOLATILE MEMORY
15
DISPLAY
17

FIG 4

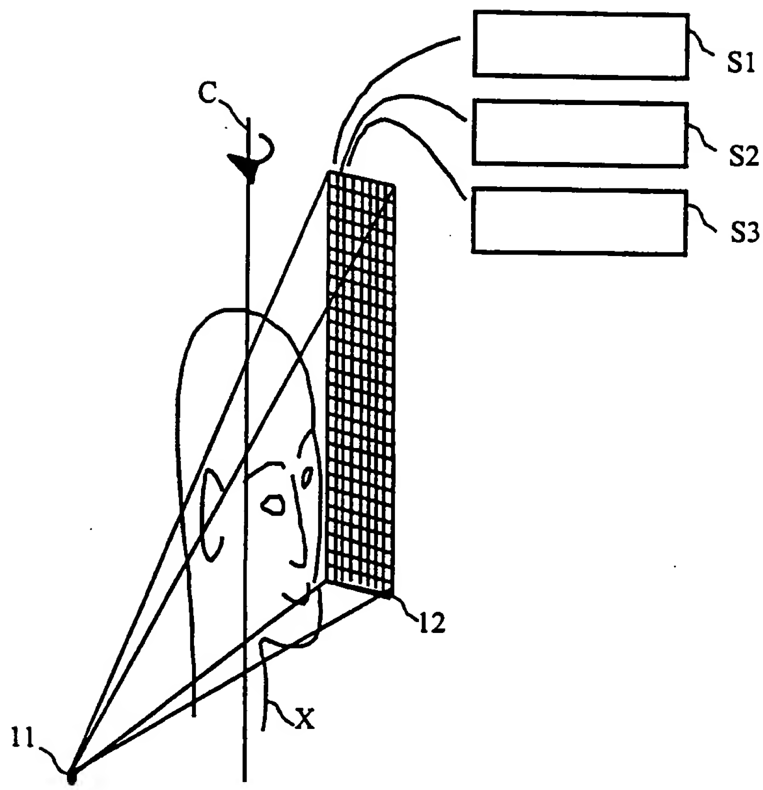

FIG 5

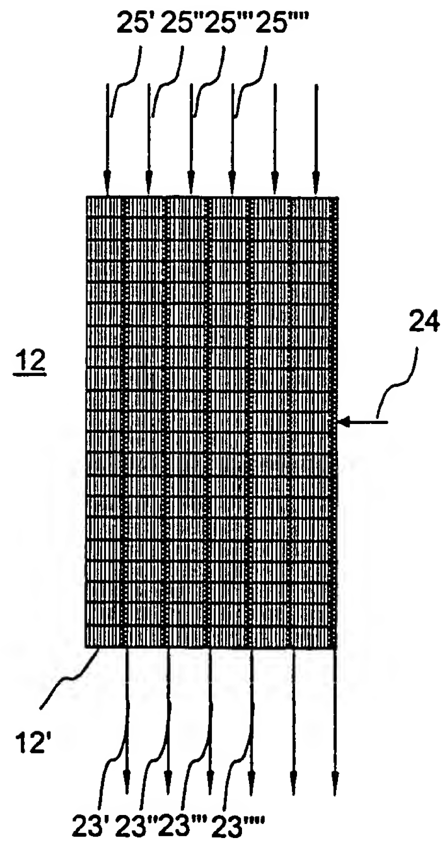

FIG 6a

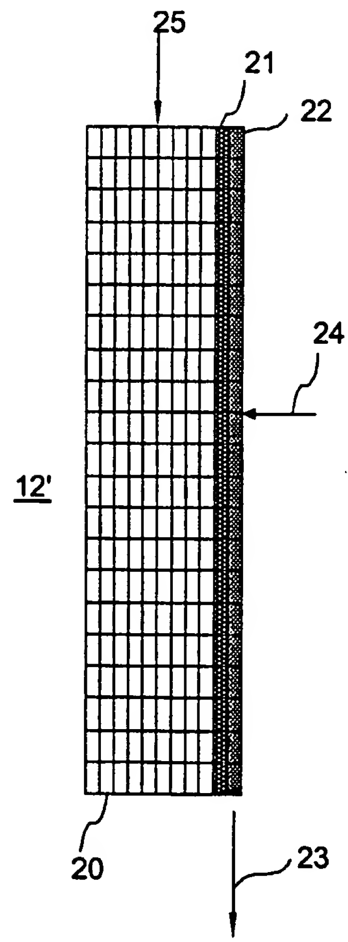

FIG 6b

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 00/00404

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: G06F 19/00, A61B 6/02
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: A61B, G06T, G06F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4482958 A (N. NAKAYAMA ET AL.), 13 November 1984 (13.11.84), column 2, line 23 - line 51; column 3, line 6 - line 66; column 6, line 48 - line 59	1-11,16-20, 24-26
	--	
A	WO 9800063 A1 (NILSSON, STEFAN), 8 January 1998 (08.01.98), figure 1, abstract	1-11,16-20, 24-26
	--	

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" erlier document but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed
- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 October 2000	23 -10- 2000
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Cilla Lyckman/AE Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI00/00404

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

See next sheet.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-11, 16-20, 24-26

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

II

The application lacks of unity à posteriori. The inventions are:

1. A method according to claims 2 and 3 including the additional features that the tomographic angle for the images in each pre-summation is less than 5 degrees.
2. A method according to claims 4-5 including the additional features that the pre-summed images are essentially composed of an equally large amount of information and that the information corresponds to a certain number of images.
3. A method according to claims 6, 16 and the corresponding apparatus according to claim 24 including the additional feature that the pre-summed images are recorded in the mass storage, and the actual tomosynthetic image is formed on the basis of the said recorded, pre-summed images.
4. A method according to claim 7 including the additional feature that the beam obtained from the radiation source is restricted to a certain form.
5. A method according to claim 8 including the additional feature that the pre-summing is partly performed during the reading of the image information.
6. A method according to claim 9, 12-15 and the corresponding apparatus in claim 19 and 21-23 including the additional feature that the radiation detector is a sensor that converts x-ray radiation directly to electric form.
7. A method according to claims 10 and 11 and the corresponding apparatus in claim 20 including the additional feature that the pre-summing is performed electronically or programmatically in a scratch-pad memory.
8. A method according to claim 17, 25 and 26 including the additional feature that the method is used for certain purposes.

These inventions could though be searched without effort justifying an additional fee. In the search on the invention numbered 6, an additional invention was found and an additional search fee was required for this invention:

1. A method according to claims 12-15 and the corresponding apparatus according to claims 21-23 with the additional feature that the sensor is a TDI-sensor, which utilises CCD technology, and the further design of the sensor.

INTERNATIONAL SEARCH REPORT
Information on patent family members

03/10/00

International application No.
PCT/FI 00/00404

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4482958 A	13/11/84	DE 3175047 D	00/00/00
		EP 0052342 A,B	26/05/82
		JP 1334023 C	28/08/86
		JP 57085174 A	27/05/82
		JP 60058504 B	20/12/85
WO 9800063 A1	08/01/98	EP 0928458 A	14/07/99
		SE 9602594 D	00/00/00